SCIENCE FOR CERAMIC PRODUCTION

UDC 666.3

PROSPECTS FOR INCREASING THE ENERGY AND ECOLOGICAL EFFICIENCY OF THE PRODUCTION OF CERAMIC ARTICLES

A. I. Zakharov,[1, 3] M. V. Begak,[2] T. V. Guseva,[1] and M. A. Vartanyan[1]

Translated from *Steklo i Keramika*, No. 10, pp. 19 – 25, October, 2009.

The prospects for using reference information on the best available technologies, published by departmental technical working groups of the European Office on Comprehensive Prevention and Monitoring of Pollution, in the domestic production of ceramic articles are examined. The European experience as generalized in the reference information can be taken into account in the development of normative regulations and in the design and operation of enterprises; this will make production more energy efficient and decrease the load on the environment.

Key words: production of ceramic articles, energy efficiency, pollution prevention, emissions of harmful substances, best available technologies.

In the modern world ceramic articles find applications in practically all spheres of science, industry, the national economy, and healthcare. This is why the production of ceramic articles is not viewed as a single industrial sector. The production of articles differing with respect to the composition of the initial material as well as the final properties unites the technology, including comminution and mixing of raw materials as well as formation and high-temperature firing. As a result, energy consumption and the close spectrum of environmental effects unite the technological schemes used in ceramic production no matter how different they may be.

Under the conditions of the world financial crisis many enterprises that manufacture ceramic articles are in a difficult position because each one finds that its problems, which are urgent but "frozen," are exacerbated — deliveries of raw materials, equipment obsolescence requiring urgent repairs, closure of lines of credit, sharp narrowing of the sales market, intensification of competition. Some enterprises, which have rapidly developed the production of building materials (for example, ceramic brick) in the last five years, predict a sharp drop in growth rate [1] while others (for example, ceramic tile manufacturing) predict a large drop in output [2]. The production of refractories is in a period of stagnation due to absence of orders from metallurgists [3]. Some skeptics assert that now the sector (like, by the way, other sectors also) is in no condition to discuss and especially adopt new ecologically desirable technologies or technical and management decisions.

To some extent this position is dictated by the stereotypes of the past: "ecologization" (this unreadable term is found even in the certificates of scientific workers in the Russian Federation) has been regarded for many years as an added expense — purification structures, environmental protection measures, and "end of the line" solutions. At the same time the concept of the best available technologies, which has been widely disseminated, espouses first and foremost the prevention of negative environmental effects by adopting solutions that are integrated into ("built into") the technological process, and reduce losses of energy, raw materials, and water by streamlining the production process as a whole.

To get a deeper understanding of the place and role of ecological innovations in production we shall give a general description of technology from the standpoint of efficient use of resources and environmental protection.

The production of ceramics is conventionally thought of as not environmentally as dangerous as, for example, the big chemistry industry. This view is associated with, first and

[1] D. I. Mendeleev Russian Chemical Technology University, Moscow, Russia.
[2] St. Petersburg Center for Science and Research in Ecological Safety, Russian Academy of Sciences, St. Petersburg, Russia.
[3] E-mail: alezakharov@rambler.ru.

foremost, the fact that natural minerals and rocks, comprising the natural background of the environment in which humans and other organisms live, are usually used as raw materials to manufacture ceramics. Salvaging of articles which have outlived their use is not viewed as a separate problem: ceramics are essentially inert in the environment and, even if not reused, they can be deposited in sites set aside for solid everyday wastes. However, the open method of obtaining the raw materials for ceramics production that is used everywhere requires that lands be taken out of use and results in the formation of neglected quarries. This effect is rarely considered when discussing the outlook for creating new enterprises. Nonetheless, a change of the landscape cannot be understated.

The enrichment of the raw materials used likewise presents a problem, since impurities which are harmful for the operating conditions of the process equipment and the final properties of the articles are often fraught with environment hazard. Examples are sulfur compounds which are formed in the process of firing articles containing sulfur oxides.

Additives that impart to mixtures (plasticizers) or finished articles (consumable additives) special properties are used in technological processes for preparing molding mixtures. As a rule, the use of such additives increases the corrosiveness of the exhaust gases exiting a furnace, which exacerbates the harmfulness of production.

The comminution of the initial components without which no ceramic can be produced requires prodigious energy consumption and results in the formation of large amounts of dust. The release of dust is a significant problem for conventional production, such as the production of construction materials. It should be noted that with the transition to a more cost-effective dry method of preparing molding pastes in the production of various ceramics the closed method of comminution and dust catching will play an increasing role in technology.

The transition to production based on the dry method will conserve water, used in the preparation of slips, and reduce the consumption of energy for removing water in the molding and drying processes. To adopt the dry method in sectors which conventionally use the slip method, for example, in the production of tiles, it is necessary to switch to a new generation of equipment for comminution and granulation, making it possible to replace ball mills and tower dispersion driers.

Water conservation in the slip method of preparing raw materials, molding by slip casting, and the wet method of glazing the intermediate product requires a high degree of organization of the technological process and the adoption of modern management systems (quality and ecological management); otherwise, waste-water purification becomes expensive.

Depending on the molding method, frequent replacement and salvaging of the spent parts of the molding equipment are necessary. This problem is especially important when using slip casting in gypsum molds, where the life cycle of a single working mold rarely exceeds 100 castings. This requires not only a continually operating and materials-intensive auxiliary shop but also a stable channel for salvaging gypsum molds.

The main energy consumption occurs in high-temperature firing of articles and preliminary removal of moisture from the intermediate product (drying). This continually operating section of production must be energy efficient and also safe. The environmental effect is due to, first and foremost, emissions of harmful substances into the atmosphere, since the main method of heating in ceramics production is convection, using hot air and stack gases as the heat carrier. The heat losses, corrosion of the metal structures in the furnace and gas lines, and elevated danger of this section of the production process make it necessary to find ways to modernize the equipment and new design solutions.

The release of dust occurs during other stages of production aside from mix preparation: treatment of the intermediate product, drying, glazing, firing, post-firing treatment, during movement of raw material and intermediate product inside the production section. Dustiness is especially prevalent in the domestic production of building materials, which often use morally and physically obsolescent equipment.

In addition, noise and vibrations are factors through which ceramics production affects the environment and worker health. Comminution and mixing of raw materials, movement of the intermediate product and articles, and the operation of pressing equipment and fans are accompanied by substantial noise and degrade the working conditions.

The rotating parts of units generate housing vibrations and require the construction of separate foundations and special packing.

On the whole, despite the low, with rare exceptions, chemical activity and harmfulness of the components in the raw material used in the production of ceramics, the production itself is characterized by emissions of dust, harmful substances, and noise and vibrations as well as substantial consumption of energy and natural resources.

It is evident that advanced technologies coupled with effective management should be distinguished not only by high product quality but also high production efficiency, including ecological safety. The successful operation of an enterprise involves meeting a host of conditions, some of which are mandatory (see Diagram 1). First and foremost there is the societal benefit from the operation of the enterprise, expressed as supplying the market with the products which have the required quality and which, like the enterprise itself, must meet safety requirements.

Common sense and, unfortunately, the regulations of many organizations associate the objective of creating enterprises (almost exclusively) with making a profit. But making a profit can only be a result, a consequence of successful organization of the work. And this, in turn, presupposes determining societal requirements and their formulation and satisfaction, taking account of their dynamics including with respect to the quality of products and services, ensuring eco-

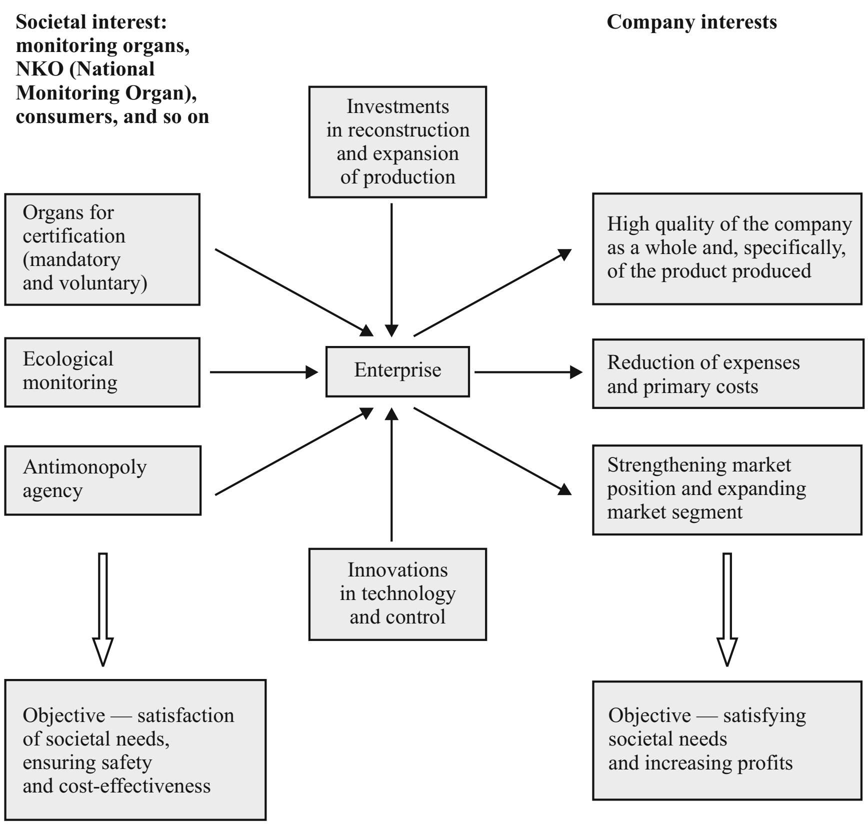

Diagram 1. Balance of the interests of society and the interests of a company.

logical and industrial safety, and increasing energy efficiency.

In modern socioeconomic systems the market must regulate product quality and benefits; all disputes between users and producers must be resolved in court. The development of a technical regulation system in Russia has as its objective the development of a legal base which, on the one hand, gives extensive possibilities for developing new products and, on the other hand, guarantees product safety [4]. In the Russian Federation technical regulations carrying the force of federal laws are issued. The recommendation nature of other documents — summaries of rules and national standards at different levels — is a reflection of the freedom of enterprise within established safety frameworks adopted for products.

A similar practice also exists in the EU, where generally accepted norms (EN) operate. However, most standards cover not the entire sphere of production but rather they are limited to the requirements for finished products and for methods of determining product properties. The international standards of quality management (ISO Series 9000) consider the entire process of production, and emphasis is placed on process consistency and optimality — from selection of raw materials to delivering a product to the user. The standards of ecological management systems (ISO Series 14,000) are geared toward improving the ecological efficiency of organizations. In a number of documents providing recommendations, used in the EU as a basis for making comparisons when analyzing the effectiveness and establishing the requirements for it, the reference documents concerning the best available technologies have firmly occupied a special place since the mid-1990s.

These reference documents are issued for sectors whose enterprises are distinguished by high consumption of energy and raw materials and significant negative effects on the environment. It is their activity that is regulated by the Directive 2008/1/EU [5] — comprehensive prevention and monitoring of environmental pollution (simply “directive” in what follows), the first version of which was adopted in 1996. The result of 12 years of work in accordance with the requirements of the directive attest that it is one of the most useful tools for control in the sphere of environmental protection. The basic approach of the directive consists in the fact that the environment is regarded as a single whole, which makes it necessary to use a comprehensive approach to preventing and monitoring pollution. In the EU large enterprises, at which the directive is aimed, are given comprehensive solutions for all forms of environmental effects.

Meeting the requirements of the directive presupposes that the best available technologies (BAT) are adopted. The technologies are the “latest developments for various forms of work, processes, and methods of product functioning, which attest to the practical utility of using concrete technological solutions as a base for establishing permissible values of emissions, discharges, and wastes in order to prevent contamination or, when prevention is impossible in practice, to use technical methods of reducing emissions, discharges, and wastes as whole” [5]. The term “technology” in the context of the directive incorporates technological processes themselves as well as technical solutions (so-called “end of the line” or environmentally protective equipment) and methods for controlling enterprises. The BAT concept also includes how an enterprise is designed, built, functions, and operates and how it will be shut down. All methods and solutions are regarded from the standpoint of ensuring the best protection of the environment while at the same time meeting the requirements of production efficiency — cost-effectiveness, energy, and resources.

The term “available” refers to “technological solutions and methods which have been developed on corresponding scales and are ready to be adopted in a concrete industrial sector” [5]. It should be noted that the methods discussed

must be cost-effective and technically feasible taking account of the balance of the corresponding cost and benefit. This is very important in the context of choosing solutions, which taken together can be referred to BAT, for a concrete enterprise. In all cases it is necessary to take account of the regional particulars (abundance of raw materials, fuel, climatic conditions, character of the dissemination of the contaminants, and so forth) as well as the particulars of the economic position of the enterprise, stages of the investment cycle, and so forth [6, 7].

The concept "best" refers to the most efficient (efficacious) methods which make it possible to reach a high level of environmental protection as a whole. In this position the emphasis was made on the inadmissibility of solutions to problems of protection on part of the environment (for example, air by installing absorbers to scrub the exhaust gases) with harm being done to another part of the environment (for example, as a result of the formation of an additional waste waters containing substantial concentrations of harmful substances).

To date reference documents on BAT have been developed for 26 sectors of industry. They are renewed periodically (once every 5 – 7 years) and are accessible to all interested parties. Specialized (sector) working groups of the European Office for comprehensive prevention and monitoring of pollution, under whose aegis the Forum on the Exchange of Information in the field of BAT has been organized, are responsible to developing and actualizing the reference documents on BAT [8, 9].

The reference document on BAT in the production of ceramic articles — a typical sector handbook — was issued in 2007 [10]. The technological and technical solutions and the characteristics of input and output flows described in them are widespread in each of the nine subsectors of ceramic production examined (brick, keramzit, ceramic pipe, refractory materials, tiles, dishware, sanitary ware, unglazed tile, abrasives on inorganic binder) and have proven their effectiveness, i.e., the document described contains arrays of data obtained as a result of benchmarking (comparative analysis) of effectiveness indicators (first and foremost, ecological effectiveness) of real, operating enterprises.

The reference document gives a brief description of each subsector as whole for the members of the EU (part 1) and a brief description of the technological processes in each of the subsectors examined (part 2). The characteristic specific levels of raw materials and energy use and production of pollutant emissions per unit of production are given (part 3).

Variants are examined for specific examples of the reduction of the consumption of resources and energy and reduction of emissions when using the measures at two levels — when introducing changes in the technology and using purification methods — "end of the line" solutions (part 4). In this part, special attention is devoted to ecological management tools. Actually, the authors present a brief exposition of the requirements for management systems in accordance with ecological management and audit system — EMAS, which is widely used in the EU [11]. Domestic readers can become acquainted with the basic principles and requirements for ecological management systems by consulting the practical guide on adopting such systems [12].

In part 5, the best methods which are accessible today for each subsector mentioned are presented and an assessment is made of the financial costs of adopting concrete technical solutions.

The advanced technological devices which are now starting to be adopted in production are discussed in part 6 of the reference document.

It should be underscored that the reference document is not a guide for designing plants or a textbook on the technology of manufacturing ceramic articles. Its audience consists of engineers – technical workers, ecological specialists in industrial enterprises, and associates in environmental protection agencies. In the EU the reference documents on BAT are finding applications mainly in the preparation of the foundations and providing the conditions for comprehensive environmental protection solutions to industrial enterprises. If the question concerns a new plant, then the corresponding reference document is cited when organizing procedures for evaluating environmental effects. The ranges given in this document for emissions, discharges of contaminants, and production of wastes must be strictly followed by the enterprise. However, if an operating plant is discussed, then the goal is to reduce the negative effects in stages, aiming at the BAT levels. The development and adoption of ecological management systems makes it possible to set realistic goals and problems and to demonstrate step-wise improvement of ecological effectiveness.

Naturally, the reference documents are also used as sources of information for training specialists — engineers, technologists, industrial ecologists, and managers. In addition, the latter concerns not only universities in the EU but also institutions of higher learning in Russia and neighboring countries [9, 13].

In Russia the EU Project "Harmonization of ecological standards II — Russia" (GÉS II, see www.ippc-russia.org) is devoted to advancing the idea of comprehensive prevention and monitoring of environmental pollution and reference documents following BAT. In the time the project has been in existence, reference documents following BAT for the production of ceramic articles, cement, and lime as well as "horizontal" reference documents on economic aspects and questions concerning effects on different components of the environment and on industrial ecological monitoring and control have been translated into Russian [http://www.ippc-russia.org/content/id/ru/207.html]. A reference document on BAT for energy efficiency has been prepared with the support of the Foundation for Strategic Programs of the British Government (see http://www.1400.ru/projects/city-climate/cover.html [14, 15]). All of these documents are freely accessible on the internet.

TABLE 1.

Period when the enterprise started operations	Specific energy consumption per ton production, GJ/ton							
	Russia				EU enterprises			
	data from the review [19]	enterprises examined		characteristics of new designs	BAT data [10]	selected plants		characteristics of new designs
		plant No. 1	plant No. 2			Austria [10]	Estonia	
1970 – 1980s	3.0 – 3.3	–*	~ 3		2.29 – 3.30	–*	~ 3	
Beginning of the 21st century	1.8 – 2.2	1.94	2.28	–	1.69 – 2.85	1.55	1.92	–
Enterprises being designed, experts' assessments	–	–	–	1.50	1.5 – 1.9	–	–	1.91 2.08 2.19

* Enterprises were created in the 1990s.

Design experience gained over the last few years [16, 17] has shown that it is impossible to organize large-scale comparative analysis of the effectiveness of domestic enterprises. Moreover, enterprises manufacturing ceramic articles do not practice open corporative responsibility and simply adopt data out of thin air as done for the chemical and petrochemical sectors.

Nonetheless, a comparative assessment of the effectiveness of some domestic enterprises with respect to energy consumption and emission of pollutants into the environment has been completed within the framework of pilot studies of the GÉS II Project [18]. Analysis showed that depending on the year operations began (reconstruction) the enterprises are approaching the level set by BAT for similar European production. A comparison of the energy efficiency of enterprises in the EU and Russia with respect to energy consumption in the production of ceramic brick at selected enterprises is given in Table 1.

We underscore that consulting a reference document makes it possible to assess the domestic and foreign design proposals from the standpoint of energy efficiency. Evidently, the plants which started operating most recently are distinguished by higher energy efficiency. Reconstruction and technical re-equipping reduce the specific energy consumption, which is valid for Russian enterprises (in the opinion of domestic experts, the energy consumption decreases by 25 – 30%) and for foreign enterprises (this follows from the nature of the "shift" of the intervals of specific energy consumption in time and is clearly demonstrated by experience in operating a plant — reconstructed soviet-era enterprise).

It can be stated that on the whole in Russia the production of ceramic materials is characterized by somewhat higher energy consumption than in the EU; this is due to certain regional particulars (climate, moisture content of the raw materials) and the approaches to control and solution of problems of energy conservation as a whole. Serious attention to these questions was first given only very recently [20]. High energy consumption together with other factors is also responsible for the relatively large effect on the environment. Specifically, the higher consumption of natural gas cannot but result in higher emissions of carbon oxides (carbon monoxide, which is a "conventional" pollutant, as well as carbon dioxide — the principal greenhouse gas) and nitrogen oxides.

The emission levels of harmful substances at domestic brick works and in a Russian plant producing ceramic sanitary ware as compared with the data in the BAT reference document [10] are presented in Tables 2 and 3, respectively.

The particulars of the technological and sanitary-hygienic normalization in Russia and the modern level of the industrial ecological monitoring and control system do not

TABLE 2.

Emissions components	Data from the reference document [10] for EU enterprises		Data on Russian enterprises		
	concentration in exhaust gases, mg/m^3	specific emission, g/ton production	concentration in exhaust gases, mg/m^3 (plant No. 2)	specific emissions, g/ton production	
				plant No. 2	plant No. 1
Dust	11.6	17.6	> 30.0	20.0	15.0
CO	124.6	189.0	1370.0	2080.0	748.0
NO_x	121.0	184.0	102.0	130.0	46.0
SO_2	26.1	39.6	No data		
Volatile fluorides	2.7	4.1		0.6	No data
Volatile chlorides	8.4	12.7	No data		

TABLE 3.

Emissions components	Concentration of harmful substances in exhaust gases, mg/m^3	
	data from the reference document [10] for EU enterprises	data on Russian enterprise
Dust	1.0 – 20.0	< 20.0
CO	< 200.0	122.2
NO_x	10.0 – 50.0	29.8

permit talking with confidence about the actual specific emissions of pollutants into the air. On the basis of the data which the present authors have at their disposal it can be supposed on the whole that the far from optimal conditions for burning natural gas at enterprises producing brick give rise to high (and even extremely high) concentrations of carbon monoxide in exhaust gases. In the EU the content of fine particles (smaller than 10 μm and 2.5 μm) is normalized [21]. In Russia the maximum admissible concentrations are established on the basis of the chemical (and not granulometric) composition of dust. Moreover, as a rule, small particles in air (and exhaust gases) are ignored, so that the indicators presented in Tables 2 and 3 should not be directly compared.

Information about the ecological effectiveness of a plant producing ceramic sanitary ware makes it possible to suppose that this enterprise has reached a level presented in the BAT document. In addition, the results of a preliminary assessment of the quality management system and the ecological management system at this plant attest that the plant management is systematically setting and solving problems concerning energy use, decreasing waste production, increasing recycling of water, and improving the quality of wastewater purification. But even in this case, because of the widely used approaches to inspection of enterprises and assessment of the effectiveness of inspection, the plant, which is actually involved in the ecological initiative, encounters definite difficulties from the standpoint of meeting environmental quality established by the norms as well as with respect to validating the priorities for developing environmental protection work.

On the whole, it appears that familiarity with the reference document on BAT by interested parties concerning the production of ceramic articles and with the procedures used in the EU for developing and using such documents could provide the impetus required to work out new approaches to assessing, gaining awareness of, and solving the ecological problems of production. The entire life cycle of enterprises must be considered — from the first conception and design of the production, including assessment of the environmental effects, licensing, and functioning and reconstruction of enterprises to shutting down enterprises.

It is necessary to prepare the soil for adopting similar approaches in our country. The conditions for this have been created: the Federal law "On technical regulation" is operative [4], the Ruling of the Government of the Russian Federation on the order of development of codices of rules, in developing which the BAT documents could have been used [23, 24], has been issued [22], and changes and additions to a number of laws will be made in the near future as decreed by the President of the Russian Federation [20]. The principles of technological normalization are gradually being implemented, which should make it possible, using the experience gained in Europe over many years, to create, adopt, and improve domestic technologies, which is in the interest of society and business (see Diagram 1). Innovations and investments in this sphere will lead to efficient use of resources and energy and decrease the negative effects of production on the environment. In turn, this will create the conditions for decreasing the prime costs and improving the user properties of products and hence for increasing the quality of Russian companies and making them more competitive. Moreover, the changes discussed above will make the work of oversight agencies with enterprises more effective and will increase the objectiveness of certification of ecological management systems of Russian organizations.

The order in which the materials in the BAT documents should be taken into account in the rule codices concerning different sectors of industry (specifically, the production of construction materials) is now being discussed at the initiative of Russian Federal Agency for Regulating Technology and Metrology [23]. In our opinion, as well as in the opinion of a number of Russian specialists who are familiar with the content of the reference documents, the transfer of European experience should consist of not so much the numerical input and output flows and even the list of technologies and environmental measures used as determining the best available technologies in Russia and creating the conditions for adopting then in domestic industry.

Even though the domestic and European industries use the same or similar equipment, in practice there are definite differences between them. They are due to the natural and historical characteristics of our country: the presence of many different climatic zones, which is manifested in, for example, the work with raw materials during the winter, and the ubiquitous use of relatively inexpensive natural gas. The availability of natural gas seems to be a good thing only at first glance — though cleaner than other forms of fuel gas is consumed inefficiently and does not stimulate the use of emissions purification systems. As noted, the ecological normalization and monitoring system differs substantially from the one adopted in the EU and is far from being able to always create conditions for improving the ecological effectiveness of enterprises. The quotas set for the use of energy resources in practice likewise are not oriented toward conserving fuel.

In this connection the European experience in implementing the differential approach of regulatory agencies to enterprises that depends on the startup time, site, and other features as well as the experience in systematic movement toward more stringent restrictions on environmental effects could be very helpful. For this, it is necessary to create work-

ing groups for different sectors, perform a detailed analysis of the present state of affairs in industry, and issue domestic reference information based on exchange of experience with the European office on comprehensive prevention and monitoring of pollution.

There is no alternative to the path proposed: using world level technology, natural resources cannot be used lavishly as in the past without any concern for the health of workers and people living near an enterprise. Analysis of designs should be based on tested solutions, which have proven their desirability and effectiveness.

It is difficult to represent in a single article the entire multifacetedness of the problems and the entire spectrum of possibilities of applying the approaches of the best available technologies to increase the energy and ecological effectiveness of production, even only for the production of ceramic articles. Materials devoted to the discussion of approaches in this field which have been validated for Russia have been prepared (www.ippc-russia.org) within the framework of the EU Project "Harmonization of Ecological Standards II — Russia (with the active participation of domestic specialists). Many seminars have been held in Moscow and regionally; the results are available on the internet. We invite all interested specialists to participate in discussions concerning this subject.

REFERENCES

1. T. L. Lygina, R. K. Sadykov, A. V. Kornilov, and P. P. Senatorov, "State of the production of wall ceramic materials in the Russian Federation," *Stroit. Mater.*, No. 4, 10 – 11 (2009).
2. Marco Santandrea, "Russia is stronger than the crisis," in: *Tile Int.*, Special Issue in Russian, MosBild, Moscow (2009), pp. 64 – 67.
3. "Russian metallurgy under the conditions of the financial crisis: information-analysis review," *Rynok Metalloprokata*, No. 1, 5 – 8 (2009).
4. "Federal law of December 27, 2002, No. 184-FZ "On technical regulation," *Sobranie Zakonodatel'stva Rosiiskoi Federatsii*, No. 52, 5140 (2002).
5. "Directive 2008/1/EC of the European Parliament and of the Council of 15 January 2008 concerning integrated pollution prevention and control (codified version)," *Official J. Europ. Union*, No. L 24/9, 24-8 – 28-18 (2008).
6. *Integrated Pollution Prevention and Control. Reference Document on Economics and Cross-Media Effects*, European IPPC Bureau (2006), electronic document.
7. "Reference Document "Economic Aspects and Questions Concerning Their Effect on Different Components of the Environment," in: *EU Project "Harmonization of Ecological Standards II — Russia,"* electronic document.
8. M. V. Begak, T. V. Gusev, and D. Khan, "Reference documents on the best available technologies: prospects for applications in Russia," *Reputatsiya*, No. 6, 7 – 9 (2008).
9. M. V. Begak and T. V. Gusev, "Prospects for using reference manuals on the best available technologies in the training of ecological engineers," in: *Proc. Interregional Scientific and Applications Conference on Continual Ecological Education: Problems, Experience, Prospects* [in Russian], Tomsk (2008), pp. 36 – 38.
10. *Integrated Pollution Prevention and Control. Reference Document on Best Available Techniques in the Ceramic Manufacturing*, European IPPC Bureau (2007), electronic document.
11. "Regulation of the European Parliament and of the Council No. 761/2001 of 18 December 2000 allowing voluntary participation by organizations in a community eco-management and audit scheme (EMAS)," *Official J. Europ. Comm.*, No. L114, 0001 – 0024 (2001).
12. S. Yu. Daiman, T. V. Guseva, E. A. Zaika, and T. V. Sokornova, *Ecological Management Systems: Practical Course* [in Russian], Forum, Moscow (2008).
13. T. V. Gusea, A. E. Khachaturov, A. V. Malkov, and S. V. Mironova, "Energy efficiency management systems and ecological management systems: experience in developing a special course for future managers," in: *Proc. Interregional Scientific and Applications Conference On Continual Ecological Education: Problems, Experience, Prospects* [in Russian], Tomsk (2008), pp. 45 – 348.
14. *Integrated Pollution Prevention and Control. Reference Document on Best Available Techniques for Energy Efficiency*, European IPPC Bureau (2008), electronic document.
15. *Reference Document on the Best Available Technologies for Energy Efficiency* [in Russian], Moscow (2009).
16. T. V. Guseva, S. Yu. Daiman, A. V. Malkov, and T. V. Serdyukov, "Energy efficiency of enterprises of key sectors of economics and decreasing the emissions of greenhouse gases: experience of international projects," *Khim. Prom.-st' Segodnya*, No. 3, 25 – 26 (2007).
17. R. Posthauer, T. V. Gusev, and S. Yu. Daiman, "European experience with the interaction of the glass industry and government for ensuring energy efficiency," *Menedzhment v Ross. i za Rubezhom,* No. 3, 56 – 67 (2007).
18. A. I. Zakharov and M. V. Begak, "Program of harmonization of ecological standards as a tool for increasing the efficiency of the production of construction ceramic," *Stroit. Mater.*, No. 4, 17 – 19 (2009).
19. M. Sh. Khusnullin, "Construction complex of the republic of Tatarstan: development factors," *Stroit. Mater.*, No. 4, 4 – 9 (2009).
20. "Directive of the President of the Russian Federation of June 4, 2008 No. 889 "On certain measures for increasing the energy and ecological efficiency of the Russian economy," *Ross. Gazeta*, Fed. Byn. No. 4680 (2008).
21. *World Health Organization. Regional Office for Europe. Air Quality Guidelines for Europe*, Second Edition, WHO Regional Publications, European Series (2000).
22. *Ruling of the Government of the Russian Federation of 19 November 2008 No. 858 "On the order of development and establishment of regulation codices,"* electronic document.
23. "Proposal concerning the legal status of Russian BREF documents," in: *Harmonization of the Ecological Standards II (GÉS II), Interim Report on the Project*, electronic document.
24. T. V. Guseva, M. V. Begak, and S. V. Mironova, "Basic principles for the development and adoption of management systems for increasing energy efficiency of enterprises," *Menedzhment v Rossii i za Rubezhom*, No. 3, 43 – 55 (2009).